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EISENHUT,D.G. Division of Licensing

SUBJECT: Discusses main steam line break analysis.Results show that peak containment pressure is not influenced by assumed addition of AFW to reuptured steam generator.Forwards assumptions used in analysis & explanation of results.

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FLORIDA POWER & LIGHT COMPANY

June 20, 1980
L-80-175

Office of Nuclear Reactor Regulation
Attention: Mr. Darrell G. Eisenhut, Director
Division of Licensing
U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Eisenhut:

Re: St. Lucie Unit 1
Docket No. 50-335
Auxiliary Feedwater Addition

The Main Steam Line Break (MSLB) analysis for St. Lucie Unit 1 has been completed by our NSSS vendor. The assumptions used in the analysis are listed in Enclosure (1).

The results of the analysis show that the peak containment pressure is reached according to the steam inventory added to the containment following the MSLB. The inventory added to the containment by boil off of the auxiliary feedwater (AFW), with an assumed delay time of three (3) minutes, is not sufficient to cause the containment pressure to experience a "second peak." In other words, under these conditions, the peak containment pressure is not influenced by the assumed addition of the AFW to the ruptured steam generator. For licensing purposes, the peak containment pressure following a MSLB remains the same as was calculated in the FSAR, and is not influenced by the AFW. An explanation of these results is provided in Enclosure (2).

Enclosure (3) discusses the Return-to-Power aspect of feedwater addition following a MSLB. It concludes that the MSLB events presented in the FSAR and subsequent reload submittals conservatively bound the MSLB event with automatic AFW initiation after a three minute time delay.

Very truly yours,

Robert E. Uhrig
Robert E. Uhrig
Vice President
Advanced Systems & Technology

REU/MAS/pa

Enclosures (3)

A001
5/3

cc: J. P. O'Reilly, Region II
Harold F. Reis, Esquire

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ENCLOSURE (1)

ASSUMPTIONS USED IN THE ANALYSIS

General Notes

All NSSS data used was identical to that used in the FSAR, except that AFW was added to the affected steam generator with an assumed three (3) minute delay.

Computer Simulation Codes

MSLB/AFW Blowdown	SGNIII
Containment Pressure/Temperature Response	CONTRANS

Note: 50% failure of the containment active heat removal system is assumed. This assumption was used in the FSAR.

NSSS Data

Reactor Power	2570
Primary Side Initial Pressure, psia	2250
Primary Side Inlet, °F	551
Secondary Side Initial Pressure, psia	813
MSLB Pure Steam Break Area, ft^2	5.355

Note: Credit was not taken for the action of the reverse flow check valve (RFCV) in the main steam lines adjacent to the affected steam generator; this assumption was used in the FSAR.

Auxiliary Feedwater Data

Flow From One Electric Pump, GPM*	750
Flow From Turbine Driven Pump, GPM**	700
Total AFW Flow To Affected Unit	1450

Note: The flow from the other electric pump was assumed to be unavailable to the affected steam generator due to AFW piping arrangement. As a conservatism this flow was not added to the unaffected steam generator since the cold AFW to the unaffected unit would indirectly inhibit the heat transfer process at the affected steam generator.

* Flow at runout extrapolated.
** Turbine pump runout flow - 1400 GPM, extrapolated
Turbine pump assumed to be at 50% RPM
0.50 x 1400 = 700 GPM

Containment Data

Free Volume, ft^3	2.5053×10^6
Passive Heat Sinks	FSAR Table 6.2-3
Initial Conditions:	
Temperature, °F	120*
Pressure, psia	14.7*
Relative Humidity	10.0%*

*The data used are the usual values recommended by CE for peak containment pressure/temperature calculations; this data was not listed in the FSAR.

Containment Spray Data

Rate, GPM (1 spray)*	2700
Setpoint, psig	10
Delay Time, seconds	60**

*Failure of 1 spray assumed.
**Assumed; not listed in FSAR.

Fan Cooler Data

Capacity (each)	60.0×10^6 Btu/hr
Delay Time, seconds	10*
Number of fan coolers	2 **

* No data was available in the FSAR. The assumption of 10 seconds delay is conservative for this plant.

** Failure of 2 fan coolers assumed.

EXPLANATION OF RESULTS

The AFW does not reach the affected steam generator until 180 seconds, by hypothesis. Consequently, there is no associated steam release to the containment until this time. By contrast, the MSLB blowdown is essentially over at about 120 seconds, so that there is an MSLB caused peak containment pressure during the first 120 seconds of the event; the time of this peak depends on the competition between the MSLB steaming rate to the containment and the sum of the spray, fan cooler, and passive heat sink removal rates. Typically, the rates described above are equal some time after the sprays are on, but before the affected steam generator is fully emptied.

Following the MSLB peak pressure, the containment pressure will continue to decrease as the MSLB steam rates decrease. This process will continue until the steaming rates are suddenly increased by the sudden addition of AFW to the affected steam generator at 180 seconds, at thich time the rate of decrease of the containment pressure slows. At this point in time the NSSS possesses adequate energy to completely boil the AFW flow; in time, as decay heat decreases and as sensible heat is removed by the boiling of the AFW, the NSSS will no longer be hot enough to boil all of the AFW. Following this time, the AFW-caused steaming rates will gradually decrease, and the AFW not boiled off will accumulate as heated water in the affected steam generator. The heating of the accumulated AFW removes a corresponding amount of energy from the primary side.

The maximum AFW steaming rate is the AFW rate itself since there is no significant stored inventory in the affected steam generator at 180 seconds; the affected unit is completely boiled dry at this time. The AFW rate is 1450 GPM, or about 200 lbm/sec. The majority of the steam is released as saturated steam, with an approximate enthalpy of 1200 Btu/lbm. Accordingly, the energy released to the containment via the complete boiling of the AFW is at most 200*1200 = 240,000 Btu/sec.

The containment vapor space will be saturated at this time since the sprays have been on for about two minutes. If the total containment pressure were, say, 40 psig (steam plus air total pressure) then the corresponding vapor space temperature would be about 264°F. Using 264°F, the fan cooler heat removal is about 33,000 Btu/sec. from two (2) fan coolers. Added to this rate is the spray heat removal rate. Since the containment is saturated, the spray rate is limited by the energy required to heat the spray to saturated liquid conditions. The spray rate is 2700 gpm (1 spray), or 370 lbm/sec. The corresponding spray heat removal rate is then about 370 x (264-95) = 62,500 Btu/sec. Consequently, the sum of the fan and spray heat removal rates from the containment is:

2 fan coolers		33,000 Btu/sec.
1 spray		62,500 Btu/sec.
	Total	95,500 Btu/sec.

While this sum is less than the 240,000 Btu/sec. associated with the full AFW boiloff, it is presented in this form to demonstrate the fact that the containment total active heat removal rate of 4 fan coolers and 2 sprays (total capacity approximately 200,000 Btu/sec) with no assumed single active failures is comparable to the AFW steaming rate. This is not unexpected since both the AFW and the containment active heat removal systems are sized with respect to decay heat removal.

The last containment heat removal term is that associated with the containment passive heat sinks. The total passive heat sink energy removal rate is, of course, the sum of the individual heat sink rates. There is no simple hand calculation for these rates since the heat conduction equation must be numerically solved for each heat sink subject to time varying containment temperatures and heat transfer coefficients. At 180 seconds, computer calculations of this process show a total rate in excess of 200,000 Btu/sec. Summing all heat removal rates now provides a total of more than 295,500 Btu/sec., compared to a maximum of 240,000 Btu/sec. input.

The above comparison clearly shows why there is no second peak containment pressure associated with the AFW. The restrictions associated with this result are:

1) 50% failure of containment sprays and fans.
2) AFW rate of no more than 1450 GPM.
3) AFW input only after 180 seconds.

This attachment illustrates the impact of automatic initiation of auxiliary feedwater system (AFWS) on the licensing cases analyzed for a Main Steam Line Break Event. The provided results of analysis for the most limiting Main Steam Line Breaks (MSLB) with respect to return to power assume this system is designed with a delay in the automatic delivery of the auxiliary feedwater to the steam generators. The analyses performed for this evaluation, therefore, allowed for a three (3) minute delay in the actuation of the AFWS subsequent to receiving a low steam generator water level trip signal. The conclusions of this analysis are considered to be applicable to the following nuclear reactor plants: Calvert Cliffs Units 1 and 2, Ft. Calhoun, Millstone Unit 2, Palisades, and St. Lucie Unit 1.

The most limiting cases analyzed were those selected from the Design Basis Events analyzed in the FSAR or subsequent reload licensing submittals, as appropriate. The most limiting case was found to be a full power-full flow Main Steam Line Break inside containment with automatic initiation of AFWS after a 3 minute delay. The analysis was continued until the subcriticality margin was continuously increasing. The delay of 3 minutes assumed as part of the design of the automatically initiated auxiliary feed system was modeled conservatively in the analysis. The MSLB outside containment is less limiting because the blowdown rate of the steam generators is restricted by the flow venturies located in the steam lines thus leading to a less severe reactivity insertion and a smaller potential for return-to-power than the results presented herein.

The results of the limiting case show that the affected steam generator blows dry in about 70 seconds and begins Reactor Coolant System (RCS) cooldown with feedwater only. The peak power level attained including decay heat and subcritical multiplication is 12%. From the time the steam generator runs dry until the actuation of auxiliary feedwater system, boron injected by High Pressure Safety Injection (HPSI), actuated at about 16 seconds into the transient, continues to add more negative reactivity to the core. After the initiation of AFW flow, the cooldown of the reactor coolant system (RCS) is resumed. The auxiliary flow is conservatively assumed to feed the affected steam generator only. The assumed auxiliary flow to the affected steam generator was conservatively taken to be about 20% of the full power feedwater flow. The continued cooldown of the RCS adds more positive reactivity which is eventually terminated by the Low Pressure Safety Injection (LPSI) flow injected due to low RCS pressure. The negative reactivity inserted via LPSI flow terminates the reactivity excursion. The return-to-power attained after the AFWS delivery is 10.7%. Thus, with the 3 minute delay in the actuation of AFWS, the auxiliary feedwater will be introduced away from the most critical time frame with respect to return-to-power and the conclusions of the MSLB events presented in the FSAR and the subsequent reload submittals conservatively bound those with the control grade automatic initiation of auxiliary feedwater systems included. A typical sequence of events, typical for operating C-E plants, for the limiting case are presented in Table 1.

The MSLB results presented in the FSAR and subsequent reload licensing submittals assumed the following consequential failures in addition to the single failure which initiates the event (i.e., the double ended pipe break inside containment):

(a) On reactor scram, the highest worth Control Element Assembly is assumed to stick in the fully withdrawn position,

(b) On Safety Injection Actuation, the HPSI and one of the LPSI safety injection pumps are assumed to fail to start.

(c) No main feedwater isolation is assumed on MSIS. The main feed flow is assumed to coastdown to 5% of full power flow in 60 seconds. (More realistically flow would ramp to zero in about 20 seconds.)

Single failures were considered in the design basis to the extent that a failure initiates the event and safety grade equipment is designed to accommodate single failures as described above and is consistent with the design basis presented in the FSAR. No consequential failures other than previously identified were considered. All control systems considered were assumed to function in the manner consistent with the FSAR.

Single failures concurrent with the MSLB (other than those identified above), as well as loss of offsite power concurrent with MSLB, are not, and have not been part of the design basis as described in the FSAR and, therefore, were not considered.

TABLE A-1

Sequence of Events for the Main Steam Line Break Event with Automatic Initiation of Auxiliary Feedwater System (Full load, Two-Loop Condition, Nozzle Break)

Time (sec.)	Event	Safety System Initiated	Setpoint or Value
0.0	Initiation of break	-----	-----
3.4	Low steam Generator Pressure trip signal occurs, MSIS initiated and Main Steam Isolation Valves begin to close.	Reactor Protection System Main Steam Isolation System	478 psia
4.3	Trip breakers open	-----	-----
4.8	CEAs begin to drop into core	Reactor Protection System	-----
10.7	Complete closure of Main Steam Isolation Valves to terminating blowdown from the intact steam generator	-----	-----
15.9	Pressurizer empties	-----	-----
16.2	Low RCS pressure, SIAS Initiated	Safety Injection System	1563 psia
22.8	High Pressure Safety Injection flow Initiated	Safety Injection System	1220 psia
64.8	Main feedwater flow completes ramp down to 5%	-----	-----
68.7	Affected steam generator liquid inventory depleted and beginning of blowdown of feedwater only	-----	-----
71.9	Peak return-to-power* occurs with a peak reactivity of $-.186\%\Delta\rho$	-----	12%

* return-to-power includes decay heat and subcritical multiplication

TABLE A-1 (Continued)

Time (sec.)	Event	Safety System Initiated	Setpoint or Value
150.0	Auxiliary Feedwater flow to affected steam generator initiated	Auxiliary Feedwater System	-----
318.7	Low Pressure Safety Injection flow Initiated	Safety Injection System	207 psia
319.9	Peak reactivity post auxiliary feedwater delivery	----	+.13%Δρ
345.1	Peak return to power post auxiliary feedwater delivery	----	10.7%